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The effects of body weight and pneumoperitoneum on pleth variability index and total haemoglobin in patients undergoing laparoscopic cholecystectomy: A prospective observational study

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Abstract

It is not clear if there is an inaccurate effect of obesity and pneumoperitoneum on non-invasive monitoring parameters. The aim of this study is to determine the effects of CO_2 pneumoperitoneum and desufflation on non-invasive monitoring variables between obese and non-obese patients undergoing laparoscopic surgery. Sixty patients were included in the study that underwent laparoscopic cholecystectomy between February 2019 and November 2019. After induction of anaesthesia, systolic and diastolic blood pressures, heart rate, duration of operation and pneumoperitoneum, pleth variability index (PVI) and total hemoglobin (SpHb) data were recorded. The patients were divided into two groups. There was no significant difference between the groups in terms of chronic diseases and duration of operation and pneumoperitoneum. No significant difference was found between the groups in PVI and SpHb values. In comparison of PVI measurement values with T0, a significant difference was found in T3, T4 and T5 in Group 2 ($p = 0.010$, 0.012 and 0.041, respectively). In comparison of SpHb measurement values with T0, a significant difference was found in T1, T2 and T3 in Group 2 ($p = 0.008$, 0.010 and 0.037, respectively). In comparison with T5, a significant difference was found in T1, T2 and T3 in Group 2 ($p = 0.023$, 0.005 and 0.006, respectively). In obese people, pneumoperitoneum can lead to errors in PVI and SpHb monitoring. Although these two parameters are very valuable in intraoperative follow-up, they should be used carefully during laparoscopic procedures in obese patients. If these parameters (PVI and SpHb) are considered to be used in bariatric surgeries, this information should be considered.

Keywords: Laparoscopic cholecystectomy, pneumoperitoneum, pleth variability index, total hemoglobin

1. Introduction

With the development of mini-invasive technique, laparoscopic procedures form the basis of general surgery. After the introduction of laparoscopy in surgery, laparoscopic cholecystectomy has been adopted as the gold standard in the surgical treatment of cholelithiasis and gallbladder diseases (1). CO_2 pneumoperitoneum method is used in exposing sufficient image and surgical field in laparoscopy. Usually, artificial pneumoperitoneum is established by CO_2 insufflation, and intra-abdominal pressure (IAP) is frequently maintained between 10 and 15 mmHg.

There are many advantages of laparoscopic cholecystectomy (such as short hospital stay, minimal postoperative pain and rapid recovery), and systemic disadvantages are associated with increased IAP. In laparoscopic cholecystectomy procedures, cardiopulmonary changes may be observed due to the pneumoperitoneum (2). Since preload is significantly affected by IAP increase, it is important to determine the effect of IAP increase on fluid response in patients undergoing laparoscopic surgery (3).

Today, hemodynamic monitoring includes static parameters such as pulmonary capillary wedge pressure and central venous pressure, as well as dynamic parameters such as pulse pressure variation and stroke volume variation (4). One of the dynamic parameters used to predict fluid response in mechanically ventilated patients is the pleth variability index (PVI) obtained by continuous and automatic calculation of pulse oximetry plethysmographic waveform variability during the respiratory cycle.

The Masimo Radical-7 (Masimo Corporation, Irvine,

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CA) device provides an easy and continuous measurement using a finger probe. This device has been validated to predict fluid sensitivity in patients who are mechanically ventilated and undergo open abdominal surgery (5, 6). A continuous, non-invasive hemoglobin level monitoring is provided simultaneously with the same probe. This has also been shown to correlate with blood haemoglobin levels (7). As this device can be used non-invasively, it has become the preferred method for hemodynamic monitoring in patient follow-up.

However, factors such as arrhythmia, hypothermia, spontaneous breathing activity, vasoactive drug use and impaired peripheral perfusion limit the availability of PVI and SpHb monitoring (8). The ability of these dynamic parameters to predict fluid response and blood loss may be affected by respiratory, hemodynamic and physical changes that cause intrathoracic pressure change (9).

There are few studies examining the effect of pneumoperitoneum and obesity on the reliability of PVI and SpHb. Both factors have previously been shown to significantly affect the cardiopulmonary physiology and function, and potentially affect the performance and reliability of these devices (10). There are studies investigating the effects of both pneumoperitoneum and obesity in gastric bypass operations, but there is no study investigating the effects of pneumoperitoneum with equal IAP in obese and non-obese patients.

The aim of this study was to determine the effects of continuous CO_2 pneumoperitoneum with a pressure of 12 mmHg and desufflation on non-invasive monitoring variables in obese and non-obese patients undergoing laparoscopic surgery.

2. Materials and methods

2.1. Subjects

This study was carried out in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Harran University (Approval Number 2019.4.20). After the approval of the hospital ethics committee, the study was registered in the Australian New Zealand Clinical Trials Registry (Trial Id: ACTRN12620000169943). Patients who underwent elective laparoscopic cholecystectomy under general anaesthesia for cholelithiasis between November 2019 and February 2019 were included in this cross sectional study. Written informed consent was obtained from all patients. Patients older than 18 years with written consent and with an American Anesthesiologists Association (ASA) physical score 1 or 2 were included in the study. Exclusion criteria were pregnancy, acute or chronic lung disease, heart failure, body mass index (BMI) below 18 and above 45, intraoperative bleeding of more than 100 mL, intraoperative inotropic support requirement and pneumoperitoneum duration > 45 min and < 20 min. All patients were fasted for at least 8 hours before surgery, and none of the patients received premedication.

2.2. Anaesthesia management and hemodynamic monitoring

Before the induction of general anaesthesia, standard anaesthetic monitoring was performed with electrocardiography (ECG), peripheral O2 saturation (SpO2) and non-invasive arterial pressure (NIBP) monitoring. The MightySat Rx Fingertip Pulse Oximeter (Masimo Corporation, Irvine, CA) probe was attached preventing it from being affected by light to the upper extremity index finger tip, where the blood pressure cuff was not attached. Induction of anaesthesia was performed by the same anaesthetist with fentanyl (2 μg/kg) and propofol (2–3 mg/kg). Rocuronium bromide 0.6 mg/kg was used as a muscle relaxant. Volume-controlled ventilation was applied to the patients after intubation. Ventilator settings were made as follows: tidal volume was 8 mL/kg according to ideal body weight, positive end-tidal pressure (PEEP) was 5 cmH2O, inspirium–expirium ratio was 1: 2, respiratory rate was 11–14 breaths/min and end-tidal carbon dioxide pressure (EtCO2) was adjusted to be 35–45 mmHg. Sevoflurane and IV remifentanil (0.25–0.5 μg/kg/min) infusion was used in the mixture of air and oxygen for maintenance of anaesthesia.

2.3. Study design

Data were collected after induction of anaesthesia in all patients. In order to minimise the effect of vasomotor tone, any stimulation to the patients was avoided 5 min before the data collection. PVI and SpHg data were recorded by the same anaesthesiologist in six pre-determined times in the end-expiratory phase.

T0 = basal value after insufflation

T1 = 5th min after insufflation

T2 = 10th min after insufflation

T3 = 15th min after insufflation

T4 = 5 min before desufflation

T5 = 2 min after desufflation

Systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), oxygen saturation (SpO_2) and $EtCO_2$ values were recorded in the same time frames. In addition, BMI, duration of operation and pneumoperitoneum of the patients were recorded. Crystalloid solution of 8 mL/kg was administered to patients before the induction of anaesthesia in order to prevent sudden decrease of blood pressure, thus minimising the impact of PVI and SpHb values. Crystalloid infusion continued at the rate of 4 mL/kg/h throughout the operation.

2.4. Statistical analysis

All statistical analyses were calculated by SPSS 22.0

(Statistical Packages for the Social Sciences, SPPS Inc., Chicago, IL, USA). The normal distribution was determined by Kolmogorov Smirnov test and histogram. All the parameters were not normally distributed probably because of the low group sizes. Non-parametric tests were used for calculations. The continuous variables were expressed as median (minimum–maximum). The categorical variables were expressed as n (%). The differences of continuous variables were calculated by the Mann–Whitney U test, and the Wilcoxon test was used for repeated measures. Chi-Square test was used to determine the difference between groups of categorical variables. $P < 0.05$ was considered as statistically significant. The sample size was determined by using the preliminary data of 10 patients. In power analysis, a minimum of 48 patients were shown for $\beta = 0.1$ and $\alpha = 0.05$.

3. Results

After obtaining the ethics committee approval, 74 patients were included in the study. Out of 74 patients, 60 patients were included in this study, after exclusion of 14 patients as per the exclusion criteria (Fig. 1).

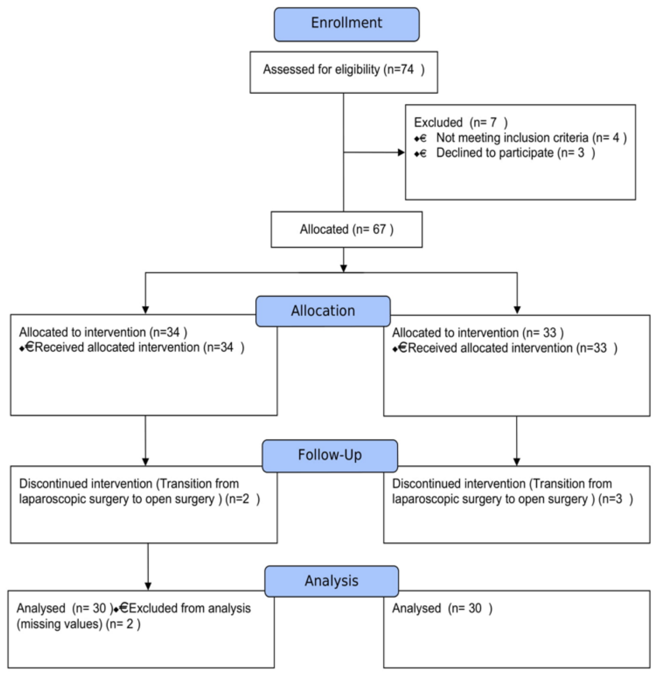

Fig.1. CONSORT (Consolidated Standards of Reporting Trials) checklist

Thirty patients with BMI < 30 were classified as Group 1, the remaining 30 patients with BMI ≥ 30 were classified as Group 2. The mean age of the patients was 38.22 ± 10.35 years, and 61.6% of the patients were women. There was no significant difference between the groups in terms of chronic diseases and duration of operation and pneumoperitoneum. Demographic data of the patients are shown in Table 1.

Table 1. Demographic data.

	Total	BMI group		p
		Group 1 BMI<30 (kg/m²)	Group 2 BMI≥30 (kg/m²)	
	median (min-max) / n(%)			
Sex (female)	18.5 (61D,6%)	18 (60%)	19 (63.3%)	0.502*
Age, years	38.22±10.35	40.05±10.23	36.40±10.52	0.235 **
BMI (kg/m²)	30.2 (19-52)	25.8 (19-29.2)	32 (30.2-52)	-
Chronic disease	10 (17.2%)	3 (10%)	7 (25%)	0.173*
Hypertension	8 (13.1%)	1 (3.3%)	7 (22.6%)	0.053*
Diabetes Mellitus	2 (3.3%)	-	2 (6.5%)	0.492*
COPD	2 (3.3%)	2 (6.7%)	-	0.238*
Operation duration	40 (28-60)	35.5 (30-60)	40 (28-60)	0.446 **
Pneumoperitoneum duration	26 (20-45)	26 (20-45)	30 (20-45)	0.253**

BMI: Body mass index, COPD: Chronic obstructive pulmonary disease

Data on SBP, DBP and HR are shown in Figs. 2 and 3.

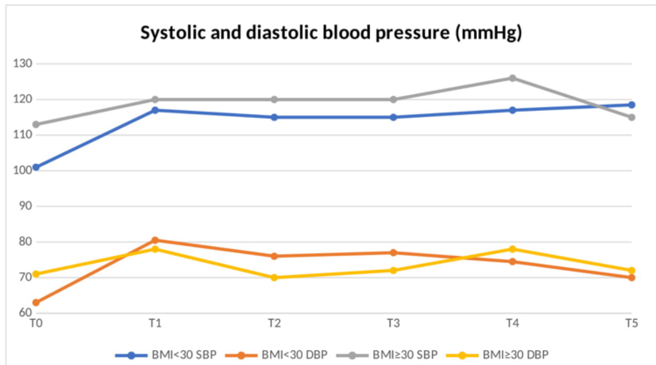

Fig.2. Systolic and diastolic blood pressure (mmHg)

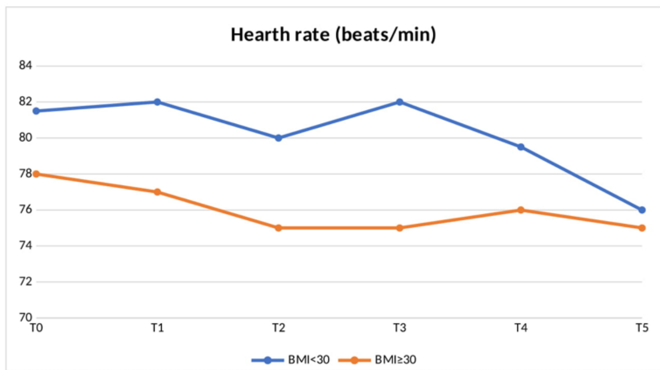

Fig. 3. Heart rate (beats/min)

From these data, it was found that only the baseline value of SBP was significantly higher in Group 2 ($p = 0.007$), but there was no significant difference between the groups in time frames and other measurements. The comparison of haemodynamic monitoring parameters between T0 and T5 is shown in Table 2.

Table 2. Hemodynamic monitoring parameters

	PVI		p*	SpHb		p*
	Group 1 BMI<30	**Group 2 BMI≥30**		**Group 1 BMI<30**	**Group 2 BMI≥30**	
T0	13 (6-45)	14 (8-50)	0.478	11.9 (9.8-14.5)	11.2 (9.7-14.8)	0.133
T1	15 (6-38)	15 (3-29)	0.729	11.2 (9.3-15)	10.9 (8.6-14.7)	0.222
T2	14.5 (8-32)	15 (5-25)	0.597	11 (9.5-15.5)	11.2 (8.8-14.7)	0.242
T3	12.5 (7-32)	13 (6-23)	0.465	11.1 (9.6-16)	11.3 (8.9-4.7)	0.239
T4	12 (6-33)	13 (4-29)	0.739	11.1 (9.8-16)	11.3 (9.1-14.8)	0.386
T5	12.5 (7-36)	15 (5-33)	0.845	10.9 (9.7-14.3)	11.6 (9-14.9)	0.756
p - Comparison with T0**						
T1	0.361	0.224		0.299	**0.008**	
T2	0.713	0.060		0.392	**0.010**	
T3	0.991	**0.010**		0.626	**0.037**	
T4	0.639	**0.012**		0.750	0.263	
T5	0.819	**0.041**		0.434	0.829	
p - Comparison with T5**						
T0	0.412	0.224		0.247	0.125	
T1	0.301	0.363		0.359	**0.023**	
T2	0.410	0.895		0.468	**0.005**	
T3	0.891	0.575		0.896	**0.006**	
T4	0.775	0.514		0.604	0.057	
*Mann-Whitney U test, **Wilcoxon signed rank test						

PVI: Pleth Variability Index, SpHb: Total haemoglobin, T0=basal value after insufflation,T1 = 5th minute of insufflation,T2=10th minute of insufflation, T =15th minute of insufflation, T4 =5 minutes before desufflation, T5=2 minutes after desufflationers

No significant difference was found between the groups at all measurement times for PVI and SpHb values. Figs. 4 and 5 show the changes of PVI and SpHb over time. Measurements of all time periods were compared with T0 and T5 separately. In comparison of PVI measurement values with T0, a significant difference was found in T3, T4 and T5 in Group 2 (p = 0.010, 0.012 and 0.041, respectively). In comparison with T5, no significant difference was found in both groups. In comparison of SpHb measurement values with T0, a significant difference was found in T1, T2 and T3 in Group 2 (p = 0.008, 0.010 and 0.037, respectively). In comparison with T5, there was a significant difference in T1, T2 and T3 in Group 2 (p = 0.023, 0.005 and 0.006, respectively).

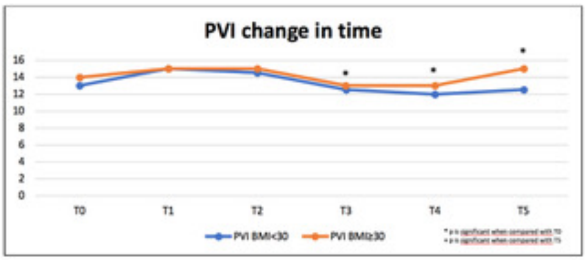

Fig.4. PVI change in time

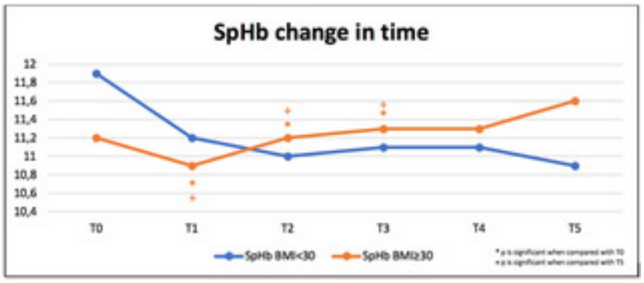

Fig.5. SpHb change in time

4. Discussion

Our study observed a false increase in PVI and a false decrease in SpHb with abdominal insufflation. Although this situation developed in all patients, it was found statistically significant only in the obese patient group (Group 2). SpHb was affected by desufflation and insufflation in obese patients.

As a result of advanced medical practices, the elderly population is increasing all over the world. Thus, the need for more surgery and the importance of haemodynamic monitoring are increase. Invasive procedures such as pulmonary artery catheters, central venous catheters and transesophageal echocardiogram require special training, increase complications, cost and application time (11, 12). Laboratory parameters such as haemoglobin and lactate and base deficit (BE) are often used in the process of intraoperative evaluation, but these measurements are not effective as they are time-consuming and expensive. Therefore, the use of non-invasive haemodynamic monitoring is increasingly important.

Estimation of blood loss and evaluation of the intravascular volume during surgery is still a major problem. Changes in intravascular volume or airway pressures can cause changes in cardiac pumping ability (13). However, as with cardiogenic shock, not all reductions in cardiac output are associated with intravascular volume. There are studies on the poor consequences of intraoperative excess fluid overload in patients. It has been reported that the application of each litre of extra fluid added to the intraoperative fluids increases the risk of postoperative symptoms and complications by 16% and 32%, respectively (14). It has been stated that patient admissions are shortened, surgical site infections are reduced and perfusion improves with sufficient but not much fluid administration (15,16). Therefore, the relevance of fluid administration has been studied for many years, and it has been reported that dynamic measurements based on cardiopulmonary interactions in mechanically ventilated patients are the best predictors of fluid response (17). Stroke volume variation, pulse pressure variation and PVI are among the most frequently used dynamic parameters in the management of perioperative fluid therapy.

PVI allows clinicians to determine fluid sensitivity in critically ill patients. SpHb allows continuous analysis of haemoglobin concentration and helps in making decisions about blood transfusions. It is especially important for operations where there is high blood loss and time loss cannot be tolerated (18). The reliability of these parameters has been confirmed in intensive care patients and open abdominal cases in the operating room (5,19,20). However, the effect of pneumoperitoneum on these parameters in obese patients is not clear.

In fact, studies evaluating the effects of pneumoperitoneum on non-invasive haemodynamic monitoring parameters have attracted attention in recent years. Hoiseth et al. (21) showed that PVI increased during pneumoperitoneum in their studies in which they investigated the dynamic variables of fluid responsiveness in patients undergoing laparoscopic surgery. Liu et al. (3) showed that PVI increased with pneumoperitoneum and PVI value decreased to pre-pneumoperitoneum values after desufflation. However, the number of studies investigating the effects of obesity is very limited. Determination of intravascular volume is critical in obese patients. Pneumoperitoneum created for adequate visualisation of the operative area in laparoscopic surgeries results in an elevated IAP. As with non-obese patients, IAP is adjusted up to 12–15 mmHg during laparoscopy in obese patients. Normal IAP of non-obese individuals is 5 mmHg or less (22). In contrast, obese patients may have a chronically elevated IAP up to 9–10 mmHg (23). Increase in IAP increases venous stasis, reduces portal venous blood flow, increases airway pressure and impairs heart function (24). To minimise these effects, it is necessary to optimise the intravascular volume to make appropriate ventilation adjustments, to use appropriate compression devices to minimise venous stasis and to minimise the effects of increased IAP on kidney and heart function. At this point, the importance of haemodynamic monitoring is obvious for intravascular volume optimisation.

In this study, in which we examined the effects of pneumoperitoneum on non-invasive haemodynamic monitoring parameters, PVI and SpHb, we observed that PVI increased and SpHb decreased by abdominal insufflation in all patients. However, these changes were only significant in the obese patient group. DeBarros et al. (13) compared open surgery, laparoscopic obesity surgery and laparoscopic surgery in non-obese patients. In this study, they identified an incorrect increase in PVI with insufflation. This finding coincides with our study. In the same study, they observed a change on SpHb with insufflation, but this change was not statistically significant.

The difference between our study and this study may be because of inclusion of different types of laparoscopic surgeries. Since we investigated the effects of obesity and pneumoperitoneum in our study, we preferred laparoscopic cholecystectomy with minimal fluid loss and bleeding that may affect PVI and SpHb measurements and a relatively short duration for operation. We tried to provide standardisation by including the single type of surgery in our study. We also tried to minimise the effects of comorbid diseases by including only ASA 1–2 patients in our study. De barros et al. included different types of laparoscopic surgeries without ASA limitation in their studies. As a matter of fact, the average ASA level was stated as 3 in their studies. These situations may be the reason for the differences between the two studies.

Our study has some limitations. First of all, it is an observational study with limited sample size. Second, we included only ASA 1–2 patients in our study. As we evaluated the effects of obesity and pneumoperitoneum in our study, we did not investigate PVI and SpHb changes that might occur because of different comorbid diseases. More studies are needed for ASA 3–4 patients. Finally, we preferred laparoscopic cholecystectomy to standardise patient groups. The amount of intraoperative bleeding was minimal, and the need for blood transfusion did not occur in any patient. Further studies are needed to evaluate the effect of obesity and pneumoperitoneum on non-invasive monitoring in large laparoscopic operations such as large oncological resections, thoracic and colorectal surgeries, where blood loss is predicted and blood transfusion is required.

As a result, pneumoperitoneum in obese patients can lead to errors in PVI and SpHb monitoring. Although these two parameters are very valuable in intraoperative follow-up, they should be used carefully during laparoscopic procedures in obese patients. If these parameters (PVI and SpHb) are considered to be used in bariatric surgeries, which are the most common surgical procedures with the combination of obesity and pneumoperitoneum, this information should be considered. According to our knowledge, this study is the first study with standardised patient groups on the reliability of PVI and SpHb of obesity and pneumoperitoneum. In order to evaluate the usefulness of non-invasive haemodynamic monitoring in laparoscopic procedures in obese patients, further research is needed in larger laparoscopic procedures.

Conflict of interest

The authors declared no conflict of interest.

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None to declare.

Authors' contributions

Concept: G.P., M.P., Design: G.P. ,M.P., T.G., Data Collection or Processing: M.P., T.G., M.K., Analysis or Interpretation: G.P., M.P., M.K., Literature Search: G.P., M.P., Y.G., M.K., Writing: G.P., M.P., T.G., M.K.

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